first a yellow and then a blue tint like steel, but when the heating is continued it burns to pentoxide. The black powder and thin wires can even be lighted by applying a match to them, as the experiment shows.

Its melting point *in vacuo* lies between 2250° C. and 2300° C., which makes it particularly suitable for electrodes in vacuum tubes, especially as it does not disintegrate. For example, it is extensively used in Röntgen tubes. Its specific weight is 16·6.

Turning now to the electrical qualities of tantalum, its specific resistance was stated by Dr. von Bolton in 1905 to be, on the average, 0·165, with a temperature coefficient of 3 per cent. between 0° and 100° Celsius.

Further experiments conducted by Dr. Pirani in the laboratory of Siemens and Halske revealed the fact that wires of various thicknesses varied in their specific resistance from 0·173 to 0·188, but after they had been heated to 1900° C. in a high vacuum for from 100 to 200 hours, they all possessed the same specific resistance, viz. 0·146, and their temperature coefficient between 0° and 100° C. had risen to 0·33 per cent.

As the temperature of a tantalum filament, when consuming 1·5 watt per candle-power, is about 1850° C., and its resistance about six times its resistance at 100° C., the temperature coefficient between 100° C. and 1850° C. may be taken, on the average, as 0·29 per cent.

No doubt the difference between these results is caused by alterations in the structure of the wires during their manufacture, and the heating *in vacuo* served a similar purpose to the annealing of steel, so that Dr. Pirani's results published in 1907 may be taken as standards.

At present the most important industrial application of tantalum is its use for filaments of incandescent lamps, which may be said to date from July, 1903, when Dr. Feuerlein succeeded in producing a tantalum wire one-twentieth of a millimetre in diameter. Of this wire he made a glow lamp with a filament 54 mm. long, using a current of 9 volts 0·58 ampere, and giving a light of 3·5 candles (Hefner), at the rate of 1·5 watts per candle-power.

A simple calculation shows that for a current of 110 volts 660 mm. of the same wire would be required, giving at the same rate of consumption of energy a light of 43 candles.

In carbon lamps, for 220 volts the length of filament is only 400 mm., and the filaments remain hard until they disintegrate. Tantalum filaments, like other metallic filaments, soften, however, to such a degree that they cannot be used in the same shape as carbon filaments.

After trying various methods of housing the long Ta filament in a glass bulb of approximately the same dimensions as the carbon glow lamps, the present form was arrived at during the year 1904. In this lamp, which was adopted as standard, the length of the filament was 650 mm., its diameter 0·05 mm., and its weight 0·022 gram, so that about 45,000 of these lamps contain 1 kg. of Ta.

Since then these dimensions have been modified to a certain extent; for instance, the diameter of the filament is now only 0·03 mm., but the external shape has not been altered.

It was soon found that after burning a short time the filament underwent certain structural changes and lost its great tensile strength. Examination under a microscope revealed the fact that in about 1000 hours the smooth, cylindrical filament shows signs of capillary contraction, as if the cylinder was going to break up into a series of drops, and the surface, from being dull, commences to glitter. This contraction of the filament after being heated is readily recognised by comparing a new lamp with an old one. On the stars of the new lamp the filament hangs loosely, while in the old lamp the filament is evidently in tension.

The characteristic difference between carbon filaments and tantalum filaments is shown by a diagram representing the influence of temperature on the electric resistance of the two filaments in proportion to each other.

In order to have the differences at once shown in per cents., the normal pressure and the normal resistance of both filaments, when giving the light of 1 candle for 1·5 watts, is marked as 100, and it is immediately seen that the resistance of Ta alters directly, and that of carbon inversely, as the temperature. Owing to this quality a Ta filament is better able to resist overheating than a carbon filament, as the following experiment shows, where two lamps, one Ta and one C, burning normally at 110 volts with 1·5 watts per candle-power, are gradually exposed to higher voltages. The C lamp breaks, while the Ta lamp stands up to 200 volts, the highest voltage available here. Of course, its useful life will be shorter than at its normal voltage.

As stated at the beginning of the discourse, the primary object of all the research was to find a filament more economical in the consumption of electrical energy than the C filament, and the following experiments will show that the Ta filament is in this respect a great improvement on the C filament. To begin with, a comparison can be made by burning a Ta and a C lamp under water, each being immersed in a vessel containing the same quantity of water. Owing to the C lamp requiring more energy to give the same light as the Ta lamp, the temperature of the water in the C vessel rises quicker than in the other vessel. Another way of showing the difference is by measuring the current taken by each of the two lamps when giving approximately the same light, or by sending the same current through both lamps in series and noting the difference in candle-power.

In conclusion, two interesting qualities of Ta should be noted. The first is that, when a Ta filament is heated in a high vacuum, it will expel any oxygen that has combined with it. It is possible to detect whether a filament contains any oxide by very gradually heating it up, when the parts containing oxide will appear brighter than those consisting of pure Ta, owing to the greater electrical resistance of the oxide.

These lamps have been purposely exposed to the air while they were being exhausted, and have become "spotty" in consequence, but if they are raised a little above their proper voltage and left burning for a few minutes their filaments become quite uniform by the expulsion of the oxygen.

The second quality is that Ta will act as a rectifier when used in an electrolyte, that is to say, it will allow the passage of the positive current only in one direction. In the apparatus shown the positive current passes through the lamp to a Ta anode, thence to a Pt kathode, but in a very short time the Ta anode covers itself with a film of oxide which stops the current. When the current is reversed the lamp lights again, and continues to burn. When an alternate current is connected to the lamp it will also continue to burn, but with diminished brilliancy.

All these experiments are intended to show the remarkable qualities of this material, and when they are fully appreciated and its limitations are properly understood there appears to be a great field open to tantalum and its industrial applications.

CONFERENCE ON ROADS.

A CONFERENCE arranged by the County Council Association, in conjunction with the Association of Municipal Corporations, the Urban and Rural District Councils' Association, the Association of Municipal and County Engineers, and the County Surveyors' Association was held in London last week, and lasted over three days. The meetings were divided into three sections, which met at the Institution of Civil Engineers, the Mechanical Engineers, and the Surveyors' Institution.

This conference was very largely attended by borough and county engineers, chairmen and members of the Roads and Bridges Committee of county councils, and others interested in automobiles.

Following on the International Road Congress held at Paris last year, this gathering together of those responsible for and interested in the management of the highways of this country shows the increasing importance of road traffic and of the interest taken in the condition of our highways.

Forty papers were contributed for reading and discussion, the subjects dealt with relating to the construction and maintenance of roads; motors and traction engines,

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their weight and speed, and effect of wear and tear on the roads; nationalisation of the roads, and Exchequer grants towards their maintenance; the collection of statistics and standardisation of these.

There can be no doubt that a very considerable change has come about in the requirements of roads since the advent of the motor-car. After the introduction of railways the main roads became very much neglected, and little interest was taken in their condition, but now they are more used than even in the old coaching days. For the traction engine, the motor-car, or the steam trolley the old methods of management are unsuitable, and the new conditions require different treatment. The greater part of the roads in rural districts may be described as having grown or developed, and have been built up by the use of the metalling placed on the surface without any foundation. This accounts for their unsuitableness for the rapid and heavy traffic with which they have now to contend, and for the excessive cost of maintenance.

The old turnpike roads, which constitute the greater part of the main roads now under the control of the county or borough councils, have been, as a rule, well made, and are under the management of qualified engineers, and on these roads considerable attention has been paid in the endeavour to adapt them to the altered circumstances; but on the highways which are under the management of rural district councils the case is different. These rural councils, from a false idea of economy, make use of perishable materials for repairing the roads, such as limestone or gravel, because these can be procured in the neighbourhood, and can be obtained at less price than suitable road material brought from a distance. With the same false idea of keeping down the cost, unqualified men are employed as surveyors at small salaries. Sometimes the only qualification that the applicant for this office possesses is that he has been unsuccessful in his business as a farmer.

In a pamphlet on the repair and management of roads, issued by the Roads Improvement Association for the use of surveyors of highways, it is clearly shown that roads well maintained and kept in good order cost less than bad roads repaired with inferior material. An example is given of a turnpike road which had been much neglected, of which, owing to change of management and the use of granite in place of local stone, the cost was not only considerably reduced, but from the improved surface of the road one horse was able to draw as large a load as formerly required double the number. In the same district it was also shown that the parish roads, which cost the most to maintain, were without exception those that were kept in the worst condition, and that when these were placed under efficient supervision, while the roads improved, the cost of their maintenance diminished.

The use of self-propelled vehicles, owing to the way in which they affect the surface of the roads, more than ever emphasises the necessity for the use of skilled supervision. There was a unanimous expression of opinion at the conference that the cost of maintaining the roads had very considerably increased, and that in many cases, owing to the want of proper foundations or inadequate metalling, they are quite unsuited for the class of traffic that they have now to bear.

In one of the papers read at the congress it was shown that to cover such roads with a coating of suitable material of a thickness of 3 inches, in place of the flint or limestone at present in use, would cost 1100*l.* per mile, or five millions of pounds for the south-eastern division of England, where the motor traffic is the heaviest, and to which the paper more particularly referred.

The cost of maintaining the main roads has been very largely increased owing to the wear and tear of automobiles. During the last nine years the annual cost of the main roads, which extend over a length of 27,600 miles, has risen from 2,024,711*l.* to 2,766,903*l.*, or at the rate of 76·1*l.* to 100·2*l.* per mile. In one of the southern counties the cost has been doubled.

A matter that received considerable attention at the conference was the nuisance due to the dust which prevails in dry weather along the roads frequented by self-propelled vehicles moving at great speed. Motor-cars not only raise and distribute dust in a manner previously unknown, but also are responsible for its production. This is especially the case on the roads that are in the worst state of repair. On a loose surface the fine particles, which act as a binding material to the larger stones, are sucked up by the tyres of the wheels and distributed over the road, causing inequalities and providing material for dust. A great deal of damage is also done by the sucking out of the water from the puddles when the road is wet. A rubber-tyred wheel splashing into a puddle sends the water flying out of it with a speed and force greater than any other vehicle, and converts a small puddle into a larger one. This effect is greatest where the surface is repaired with soft material, or where the material used for binding is unsuitable. On roads under the management of unskilled surveyors any material is considered sufficient for binding the larger stones used for covering the surface of the road. The scrapings of the mud off the road in winter are often made use of for this purpose, and in one of the papers read at the conference it is stated that in one district even material was dug from the sides of the road, and the metalling bedded with this. Under such practices the result, of course, cannot be otherwise than a muddy surface in winter and dust in dry weather.

Various processes have been tried as a means for preventing the generation of dust, but the one most generally adopted in this country is to make the surface of the roads waterproof by the use of pitch or tar, either as a matrix for binding the stones together or as a surface dressing. Already 1500 miles have been treated in this way. The best results are obtained where there is a good foundation, and a surface covering of sufficient thickness of the hardest and toughest material, well consolidated by rolling, with just sufficient fine chippings of the same stone to fill the void spaces, the surface being rendered impervious to water or the action of frost by the use of tar or some bituminous material. Tar macadam, which consists either of the whole material used or only of the binding material being mixed with tar before being placed on the road, has been largely used. Opinions varied as to the use of this process. In some cases it has been a complete success, in others a failure. This is probably owing to the manner in which the material has been prepared and laid, and to the quality of the tar or pitch used. To be successful it requires that the material must be mixed with the tar when it is dry, and dry weather is required when it is put on the road. If improperly mixed it either breaks up in patches, which are difficult to repair, or becomes so soft in hot weather as to work into a very uneven surface.

For surface dressing on roads already made and in good condition, spraying with tar either by hand or by a machine made for the purpose is effective, and as it adds considerably to the life of the road it does not add much to the cost of maintenance.

No reference was made in any of the papers to the practice in use in the United States, and which now extends over many hundreds of miles in California and other States, of using petroleum or bituminous oil for spraying instead of tar, which is there found to be very effective. The oil is spread from a specially designed tank-car at a rate varying from one to two gallons to the square yard. Roads so treated are fit for traffic twenty-four hours after being sprayed; they are thus rendered impervious to rain-water, and the surface remains hard and firm in hot weather.

MAGNETIC SURVEYS.[1]

THE first volume referred to below may be regarded as the coping-stone of the work done for the Coast and Geodetic Survey by Dr. Bauer during his tenure of the office of chief of division of terrestrial magnetism. Dr. Bauer had actually transferred his services to the Carnegie Institution of Washington before the volume

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[1] Department of Commerce and Labour, Coast and Geodetic Survey, United States Magnetic Tables and Magnetic Charts for 1905. By L. A. Bauer Pp. 154. (Washington: Government Printing Office, 1908.)

Magnetic Survey of the Dutch East-Indies, 1903–7. By Dr. W. van Bemmelen. Pp. 69; with charts. (Batavia: Government Printing Office, 1909.)

Survey of India. Extracts from Narrative Reports, 1906–7. (Calcutta: Superintendent Government Printing, 1909.)

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